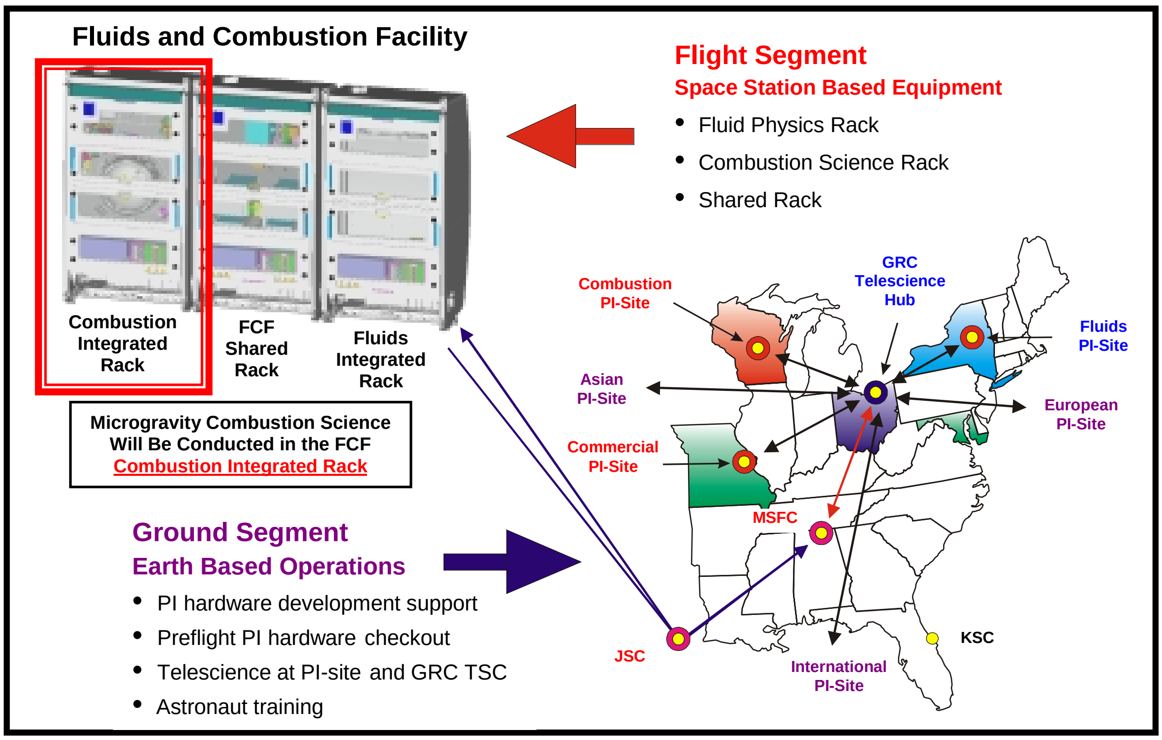
ISS FLUIDS AND COMBUSTION FACILITY

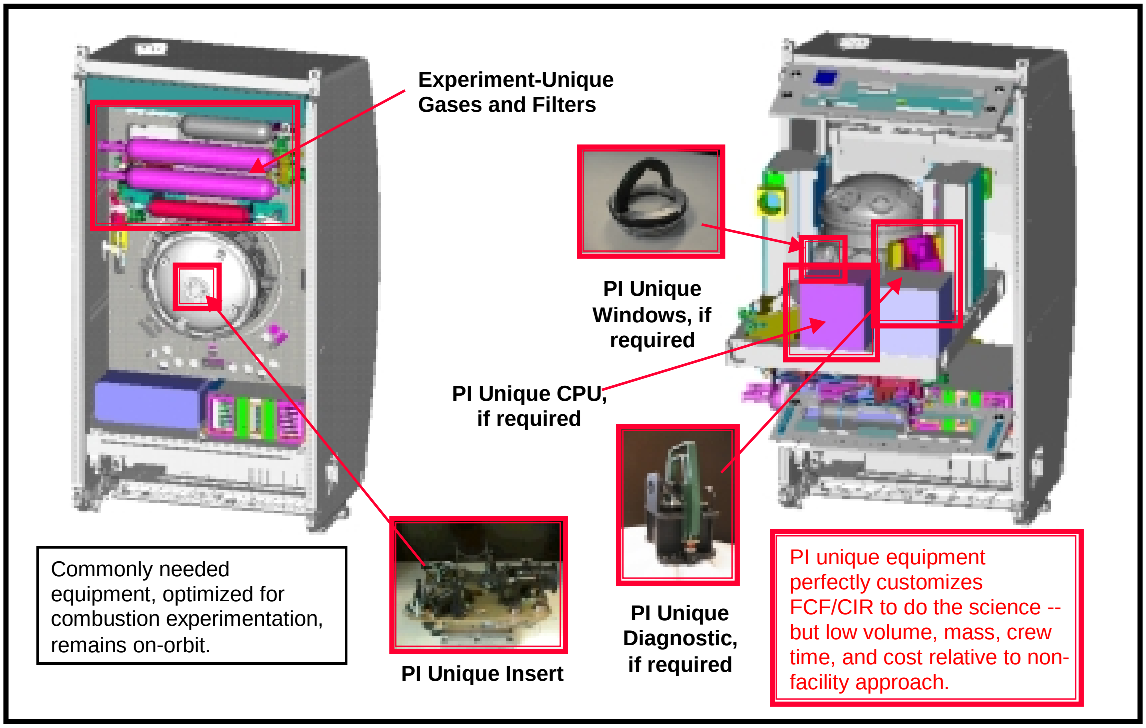
The ISS Fluids and Combustion Facility (FCF) is a modular, multi-user facility that will support Microgravity Fluid Physics and Microgravity Combustion research on board the International Space Station. The FCF will be a permanent on-orbit research facility that will enable NASA's Human Exploration and Development of Space (HEDS) Microgravity Program objectives to be met. The FCF is being designed to support sustained, systematic research in the ISS over the ten to fifteen year lifetime of ISS, after its assembly has been completed on-orbit. The facility is being designed to accommodate 5 to 15 Fluid Physics experiments per year and 5 to 15 Combustion Science experiments per year, depending upon ISS resources and Microgravity Research Program resources that are made available to support investigations in these research disciplines.



The FCF Flight Segment will consist of three on-orbit racks that will be located inside the US Laboratory Module of the ISS. These racks are the Combustion Integrated Rack (CIR), the Fluids Integrated Rack (FIR) and the Shared Accommodations Rack (SAR). The Combustion Integrated Rack will be optimized to support a diverse range of microgravity combustion science investigations on-board ISS. It will be the first FCF rack deployed to ISS and is currently planned for launch to ISS on UF-3 in 2003. The CIR will initially operate independently from other FCF racks, supporting the first set of microgravity combustion science investigations on board ISS. After other FCF racks are deployed to ISS, the CIR will operate in conjunction with those racks to leverage their capabilities, thereby maximizing combustion experiment through-put and science return from ISS.

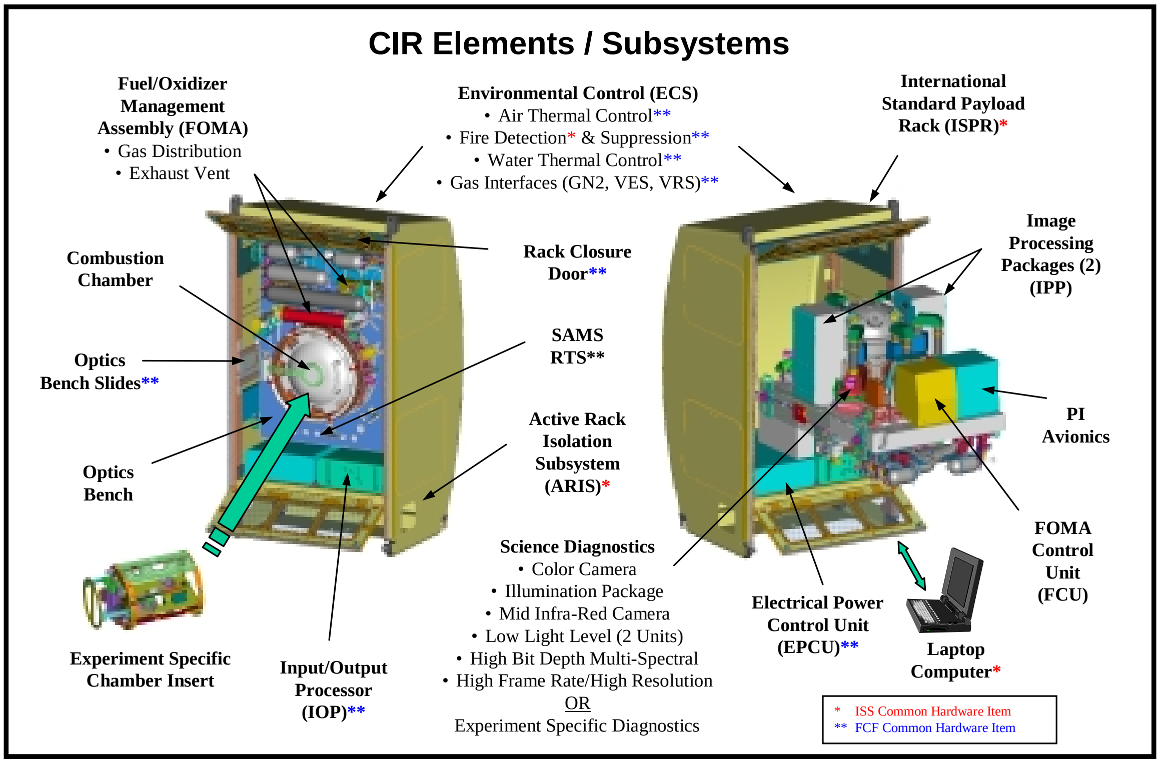
FCF COMBUSTION INTEGRATED RACK

The FCF Combustion Integrated Rack (CIR) will provide a platform for sustained, systematic microgravity combustion research on-board ISS. Principal Investigators will be able to use this microgravity environment to isolate and control gravity-related phenomena, and to investigate processes that are normally masked by gravitational effects and thus are difficult to study on Earth. A diverse range of combustion research can be accommodated in the CIR, including (but not limited to) studies of laminar flames, reaction kinetics, droplet and spray combustion, flame spread, fire suppressants, condensed phase organic fuel consumption, turbulent combustion, soot and polycyclic aromatic hydrocarbons and material synthesis.



The CIR will provide the majority of required hardware and infrastructure to perform combustion science investigations in ISS. In this way the cost and development requirements for individual experimenter's hardware is minimized. However, key components of the CIR will be on-orbit replaceable to enable it to be customized for each new combustion experiment that will be performed in it. The CIR's modular, flexible design will also permit upgrades, incorporation of new technology and provide for on-orbit maintenance during the >10 year life span of the facility.

A Principal Investigator that plans to use the CIR as a research platform for combustion experimentation will typically develop science-specific equipment that will be installed in the CIR to perform the experiment. The following types of hardware and software items may be needed to tailor the CIR to accomplish the specific research objectives of a microgravity combustion experiment: Intrusive diagnostics (i.e. thermocouples); igniters; sample cells; combustion chamber insert; experiment gases (contained in FCF-provided bottles); exhaust vent filter(s); science-specific diagnostics; Specialized electronics; control software (scripts).



The CIR will provide an optics bench for combustion experimentation in ISS. The layout of the bench can be optimized for each new combustion experiment. A 100-liter combustion chamber is located in the center of the optics bench. It incorporates eight windows, which can be replaced on-orbit. Windows will be selected for the wavelength of lights most important to the PI and/or changed out if contaminated. The CIR's Fuel Oxidizer Management Assembly (FOMA) will deliver gaseous fuels, diluants and oxidizers to the combustion chamber. The FOMA can support static and dynamic mixing of gases with very high precision and accuracy. This assembly also provides for access to vacuum and cleaning of combustion by products to make them safe to vent overboard after the experiment is conducted. The composition of gases in the combustion chamber will be measured using the CIR gas chromatograph. Illumination sources and cameras covering a wide spectral range for various scientific measurements can be mounted outside each combustion chamber window. These cameras and light sources can be removed and replaced quickly, with all electrical and data connections made automatically upon crew installation. The final alignment of the cameras and their operation will be by remote control from Earth.

CIR PAYLOAD ACCOMMODATIONS

The following payload accommodations are available to an experiment performed in the CIR. More detailed information about the CIR can be found at the following web site: http://einstein.lerc.nasa.gov/fcfsite/cirpdr/index.html.

***Optics Bench*:**
- **Front/Rear Access:** Bench folds down
- **UML's:** 9 universal mounting locations for diagnostics and avionics.
- **Bench Dimensions:** 90.2 width x 124.5 length x 10 cm depth

***Gas Delivery System*:**
- **Gas Bottle Sizes and Pressure**: 3.8, 2.25 and/or 1.0 liter gas bottles. Up to 14 MPa (2000 psig) bottle pressure
- **Diluents**: Nitrogen ISS-supplied. Others PI-provided in 1.0, 2.25 or 3.8 L bottles.
- **Oxidizers**: Up to 85 O2% in 1.0 L bottle; 50% O2 in 2.25 L; 30% O2 in 3.8 L bottle.
- **Fuels**: 1.0 L or 2.25 L bottles
- **Flow Rates:** Oxidizer/Diluent - 30 SLM each manifold (90 SLM max). Fuel- 2 SLM
- **Pre-Mixed Gases:** Can be used (bottles).
- **On-Orbit Gas Blending**: Can blend up to 3 gases on-orbit (Factor 4 weight savings)
- **Static Gas Blending**
  - Partial pressure method using chamber
  - < ±0.2 % absolute gas blend accuracy
- **Dynamic Gas Blending:**
  - Mass flow controllers used
  - Accuracy for Oxygen Blends
    - < 25% O_2: ± 1.0% absolute
    - > 25% O_2: ± 2% of reading
  - Flow Rate Accuracy: ± 1.0 % of MFC F.S.

***Exhaust Vent System*:**
- Adsorber cartridge/re-circulation loop cleans post-combustion gases to ISS limit
- **Adsorber Cartridge Sizes:**
  - Large: 76 mm ID x 355mm L
  - Medium: 51 mm ID x 279 mm L
  - Small: 25 mm ID x 203 mm L
- **Adsorber Cartridge Contents**
  - Silica Gel: H20, alcohol, aromatics, olefin
  - Molecular Sieve: Removes water
  - Activated Carbon: Hydrocarbons
  - Lithium Hydroxide: CO2, Acid gases
- **Recirculation Flow Rate:** 20 SLM max.
- **Flow Through w/ Real Time Vent:** TBD

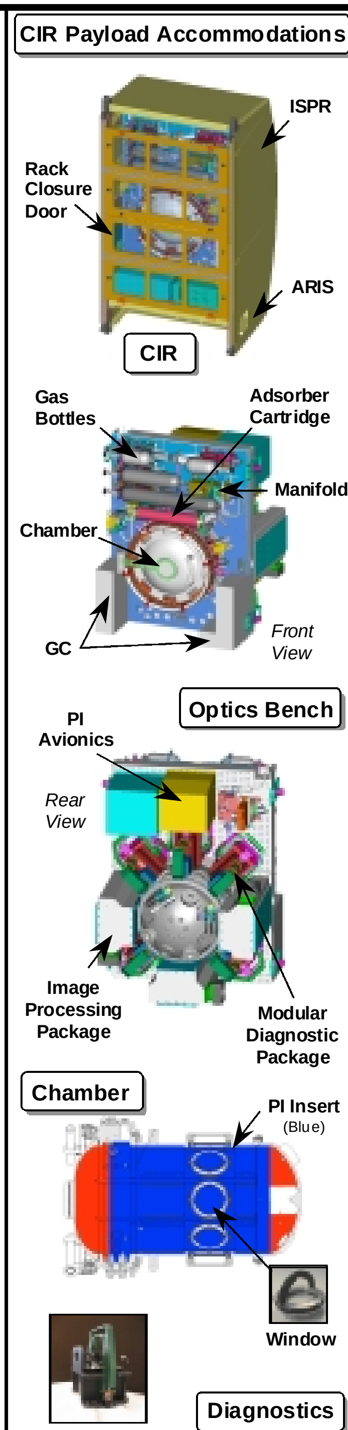
***Gas Chromatograph*:**
- Samples chamber gases prior to venting
- **Lower Detection Limit:** 100 ppm (depending upon compound)
- **Detection Accuracy:** ± 2.0 %

***Thermal Control*:**
- **Air cooled diagnostics at UML's** - 450 or 225 watts, depending on UML.
- **Water Cooled PI insert in chamber**: Up to 3 kW heat rejection to water. 17.2 C inlet temperature. Min. flow rate 25 lb/hr.

***ISS-Supplied Gases/Vacuum*:**
- **Gaseous Nitrogen**: 4.4 kg/s max. flow
- **VES**: Used for bulk gas removal. Throughput of 0.13 Pa*liter*sec @ 0.1 Pa
- **VRS**: Used to maintain long duration vacuum (<0.1 Torr) with minimal flow rates

***Electrical Power*:**
- 28 Vdc, 8 amp circuit(s) at each UML
- Three 120 Vdc x 4 amp circuits for PI TBD

***Operations*:**
- Telescience from GRC TSC and PI Site



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CIR Web Site: **http://einstein.lerc.nasa.gov/fcfsite/cirpdr/index.html**

***Combustion Chamber*:**
- **Internal Volume**: 101 free liters
- **Internal Dimensions**: 40 cm dia/90 cm long
- **Pressure Rating**: Vacuum to 135 psia (8.2 atm) maximum design pressure.
- **PI Access**: Breech lock front lid for quick crew access to PI insert in chamber
- **Mechanical interface**: PI insert interfaces to chamber via rails at 22.5°+/- horizontal
- **PI Viewing Ports**: Eight window locations, enabling 3 simultaneous orthogonal views.
- **PI Access ports:** Ports at rear of chamber

***Window Specifications*:**
- **Field of View**: 115 mm diameter
- **Window Materials**: Fused silica: 0.2-1.0 μm, Sapphire 0.17-5.5 μm (TBD), ZnSe: 2.5-10 μm (TBD). Other materials PI-qualified to fly
- **Window Position**: 20.0 cm centerline from optics bench. 4 Pairs, 180 degrees Apart

***Chamber PI Interfaces/Resources*:**
- **Electrical**: Four electrical feed-throughs deliver up to 440 Watts (28 V, 4 amp circuits)
- **Cooling Water**: Secondary cooling water loop provides 25 to 300 lb/hr water flow, with 6.35 psid available delta P. 17.2 C inlet temp
- **Pressure transducers**: Two at rear end cap with ranges up to 50 and 100 psia +/- 0.04% accuracy. Two at IRR with range up to 50 psia +/- 0.05% accuracy.
- **Thermistors**: Two at IRR with range of -75 C to 300 C and accuracy of +/-0.05% C over range of 15 C to 35 C.
- **High Pressure oxidizer/diluent supply**: Gaseous oxidizer/diluents up to 2000 psig.
- **Static Mixer Port**: Provides oxidizer/ diluents to the chamber blended dynamically & allows partial pressure mixing in chamber
- **Fuel Port**: Delivers gaseous fuel to chamber. Liquid fuels supplied w/ PI insert.
- **Automatic Vent:** Allows chamber gas recirculation with return at rear of chamber.
- **Manual Vent:** Enables evacuation of chamber when CIR is unpowered.
- **GC Sampling of Chamber Gases**: Global sampling of chamber contents.

***Diagnostics*:**
- **Baseline CIR Digital Cameras**:
  - HiBMs, Laser Illumination, HR/HFR w/ APT, Low Light Level UV (2), Mid IR
  - 6 Locations, replaceable on-orbit with PI-provided cameras
- **Image Processing Packages**:
  - 36.4 Gbytes of image data storage direct to disk at 30 MB/s.
  - Sustained image recording > 20 minutes

***PI Hardware Specifications*:**
- **Chamber Insert**: Maximum dimensions of 600 mm long x 396 mm dia.
- **Test Section:** maximum dimensions: 450 mm (axis); 300 mm (width); 180 mm (height)
- **PI Avionics**: 30.9 x 27.0 x 26.4 cm. 440 Watts; Air cooled.

***Vibration Isolation*:**
- Active Rack Isolation Subsystem (ARIS)
- 10-5 to 10-6 g acceleration environment over frequency range from 0.01 to 10 Hz

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PAYLOAD PROCESSING AND INTEGRATION SUPPORT

An extensive amount of ground support equipment will be made available to support processing, integration and check-out the Principal Investigator's experiment hardware and software prior to flight. In addition to the on-orbit CIR flight rack, there will be three additional supporting racks on earth. They are a Ground Integration Unit (GIU), an Experiment Development Unit (EDU), and a Payload Training Center (PTC) Trainer.

Engineering Development Unit (EDU)
The CIR EDU will be a high fidelity model, very similar to the CIR flight model. It will be located at GRC and made available to experiment developers during their hardware and software development and pre-flight testing. This unit will be used for interface verification and configuration selection testing.

Payload Training Center (PTC) Trainer.
The Payload Training Center (PTC) Trainer, which will be deployed in the PTC at Johnson Space Center (JSC), supports crew training. It will contain flight-like crew interfaces, and be comprised of mock-ups, brassboard level components and other non-flight components. The PTC Trainer will include a standard experiment equipment trainer, that can be used to train on the installation of a generic experiment chamber insert or modular experiment computer. This fully integrated PTC Trainer will be supplemented with experiment specific part task trainers, as necessary, that may be required to train the crew on the operation and maintenance of the experiment hardware.

Ground Integration Unit (GIU)
The CIR GIU will be located at GRC and will be used for final interface verification testing of experiment hardware, as well as for on-orbit troubleshooting. The GIU will be virtually identical to the CIR flight unit.

<u>Experiment Integration and Operation</u>
Because the FCF and CIR hardware are designed to reduce the overall cost of individual experiments by providing substantial common capabilities, the experiment equipment alone cannot perform the scientific objectives of the experiment. Therefore, a multi-tiered integration support scheme, consisting of CIR simulator, experiment engineering, and experiment flight hardware integration testing, is envisioned.

FCF Simulator Testing
Simulators of FCF/CIR flight hardware will be available to experiment developers during the development of their hardware. Simulator equipment will be designed to emulate those interfaces between the facility and the experiment that must be tested early and often throughout the experiment development, so as to assist in the design of the experiment hardware and software. Simulators for the CIR will be produced to simulate, at a minimum, electrical and C&DH interfaces, and be

used extensively for interface verification testing between the facility and the experiment.

Simulators of available FCF/CIR configurable equipment, such as cameras, light sources, filter cartridges, etc will also be provided for PI use. Early in the experiment development cycle, the FCF/CIR configurable equipment will require evaluation for suitability for use on a particular experiment. In addition to this engineering evaluation, diagnostic simulators may be required to support science testing prior to the experiment Requirements Definition Review.

Once a particular piece of FCF/CIR configurable equipment has been selected for use by an investigator, the experiment developer must conduct testing to optimize the configuration of the equipment. This testing will be used to select the settings, parameters, test sequence, and overall configuration of the FCF/CIR configurable equipment.

Experiment Engineering Hardware Testing

The next level of integration support conceptualized is testing between experiment engineering hardware and the CIR EDU. This testing will satisfy the following objectives:

- Interface verification (mechanical, electrical, thermal, software and fluid)
- Preliminary science acquisition
- Preliminary FCF configuration and parameter selection
- Test sequence identification
- Crew procedure validation

This testing will nominally occur 24 months prior to launch, and is expected to last 2-3 weeks for each experiment.

Experiment Flight Hardware Testing

Eventually, the experiment flight equipment will be integrated into the EDU to satisfy the following objectives:

- Interface verification (mechanical, electrical, thermal, software and fluid)
- Ground science acquisition
- Final CIR configuration and parameter selection
- Final test sequence identification
- PI familiarization training
- Experiment acceptance testing

A flight-like user interface will be provided at this stage of the integration testing. This testing will nominally occur 15 to 9 months prior to launch, and is expected to last 2-3 weeks for each experiment.

GIU Testing

The last level of integration support, which provides the highest fidelity integration testing platform, is referred to as the Final Interface Verification Testing (FIVT). Completely tested and accepted experiment equipment will be integrated into the GIU. This test will consist of high-fidelity interface verification, and will include an abbreviated mission simulation in order to fully exercise the software interface. This test will last approximately 1-3 days and occur approximately 1 to 2 months prior to shipping the hardware to KSC. The hardware and software configuration will be frozen at the successful conclusion of this test. If any changes in hardware or software are required after the FIVT, the FIVT will normally be repeated.

Operations

As mentioned above, command and control of microgravity combustion experiments conducted on-board ISS in the FCF/CIR will be orchestrated from the TSC located at the Glenn Research Center. The TSC is responsible for distributing the necessary voice, video and/or data to the remote PI site.

Post-Landing Payload Activities

Some PI's may require additional ground data to supplement the actual microgravity data obtained aboard the ISS. If necessary, the EDU will support additional science acquisition, on a non-interference basis. This testing, when necessary, is expected to last approximately 1-2 weeks.

TERMINOLOGY AND ACRONYMS

CIR Combustion Integrated Rack

FCF Fluids and Combustion Facility

FIR Fluids Integrated Rack

GRC Glenn Research Center

ISS International Space Station

L-24 Launch minus twenty four months

NRA NASA Research Announcement

OLMSA Office of Life and Microgravity Sciences and Applications

PI Principal Investigator

PM Project Manager

PS Project Scientist

RDR Requirements Definition Review

SAR Shared Accommodations Rack

SCR Science Concept Review

SRD Science Requirements Document

Science Panel Consist of qualified scientists in the field, including members from previous review panels with prior knowledge of the experiments as appropriate. The Program Scientist will act as an ex-officio member of the Science Review Panel. This panel will review the science requirements to determine their scope and maturity, and verify the need for the microgravity environment. They will also review the results of the science feasibility demonstrations and the explicit experiment, which is being proposed. They will review the emerging conceptual hardware design to identify engineering feasibility issues to be addressed during the hardware Definition Phase.

UF-3 ISS Utilization Flight #3